

THE AMERICAN MINERALOGIST, VOL. 52, MARCH-APRIL, 1967

SERPENTINIZATION CONSIDERED AS A CONSTANT VOLUME
METASOMATIC PROCESS: A DISCUSSION¹NORMAN J. PAGE, *U. S. Geological Survey, Menlo Park, California.*

Thayer (1966) argues that serpentinization of a primary ultramafic rock proceeds at constant volume with a removal of about 30 weight percent of the original peridotitic material in solution. He further argues for the mobility of MgO, FeO, CaO and SiO₂ during the serpentinization process. Much of Thayer's argument is based on his Figure 1 in which the sum of the bivalent oxides and SiO₂ are plotted against combined water for a large number of "ultramafites." Inasmuch as the bivalent oxides are lumped in this figure, Thayer is unable to evaluate the ratios of bivalent oxides removed with increasing water content during constant volume serpentinization, although he implies that MgO is quantitatively the most important (p. 692), that the FeO:MgO ratio is probably constant (p. 695) and that the CaO removal seems to be irregular (p. 692). I recently completed a similar study, however, which considered the bivalent constituents separately (Page, 1966). My work suggests that the ratio of CaO to MgO removed is consistently larger than the ratio of these oxides in the original periodotite.

I calculated, by means of a computer program, CIPW norms for analyses of ultramafic rocks published by Bailey and Everhart (1964), Green (1964), Hess (1960), Hess and Otalora (1964), Onuki (1963), Rigault (1958), Ruckmick and Noble (1959), Worst (1958), and others as listed in Page (1966, p. 286-339). This selection of analyses is similar to the one discussed by Thayer (1966, p. 688). Figures 1a and 1b show these norms plotted for fresh ultramafic rocks and serpentinites respectively in terms of normative diopside (DI), hypersthene (HY) and olivine (OL). Comparison of Figures 1a and 1b suggests that during serpentinization there is a loss of the diopside normative molecule. Since the diopside molecule in these analyses is directly proportional to the molecular ratio of CaO present, Figures 1a and 1b suggest a regular and absolute loss of calcium during the serpentinization process. The ratio of CaO loss to MgO loss can be evaluated by diagrams similar to Thayer's Figure 1, if these two constituents are plotted independently. My collection of analyses (Page, 1966) are plotted as weight percent CaO versus H₂O and MgO versus H₂O in Figure 2a and 2b. Figure 2a, like Figures 1a and 1b, suggests consistent CaO migration during serpentinization; however, Figure 2b does not indicate much MgO migration. If one follows Thayer's

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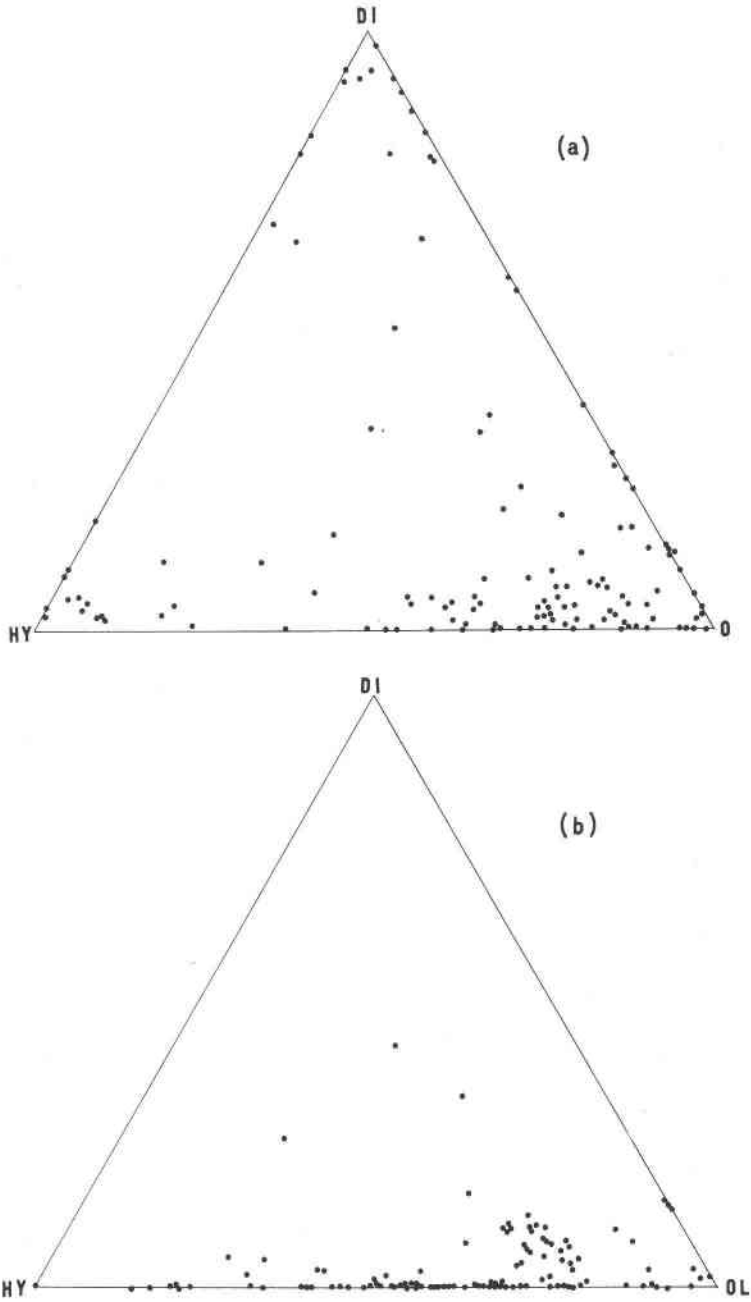


FIG. 1. Comparison of normative olivine (OL), hypersthene (HY) and diopside (DI) compositions. a. Fresh ultramafic rocks. b. Selected serpentinites.

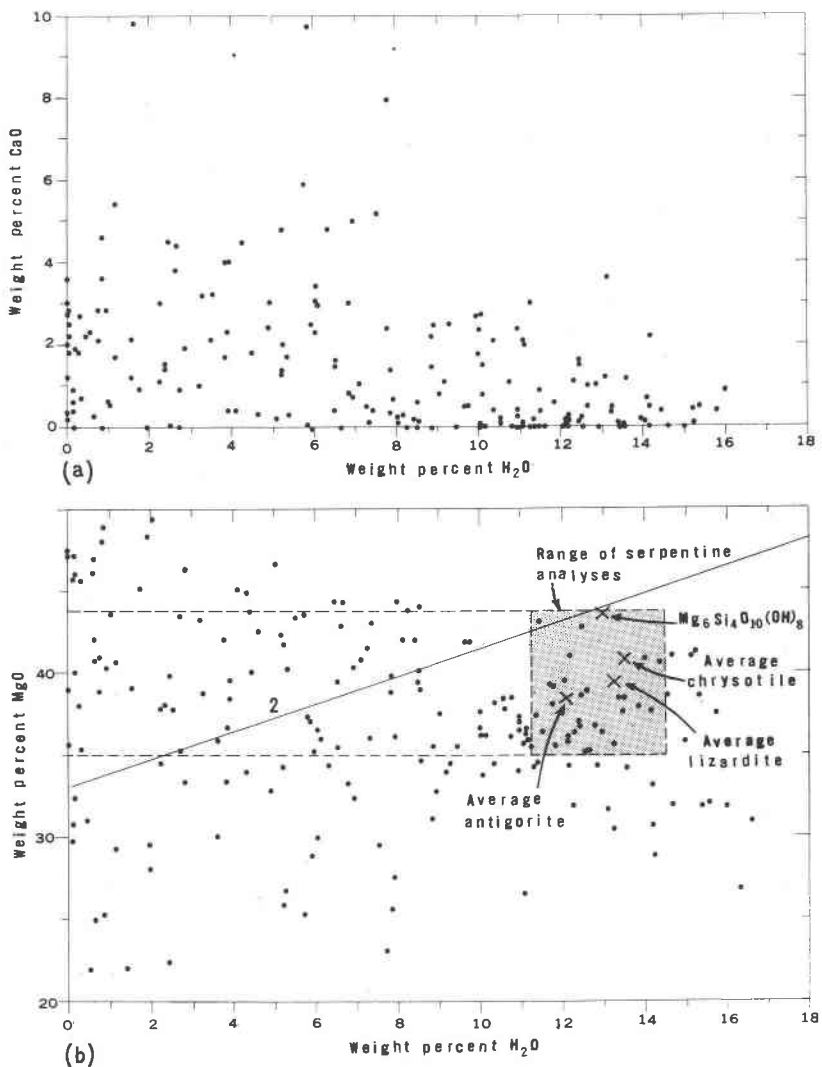


FIG. 2a. Correlation for ultramafic rocks. a. Weight percent CaO and weight percent H₂O. b. Weight percent MgO and weight percent H₂O for ultramafic rocks. Averages and ranges from Page (1966). Line 2 represents a least-squares analysis for the line with the best fit for the data.

reasoning, therefore, it is apparent that the ratio of CaO loss to MgO loss during serpentinization is very large.

I would also like to point out that Thayer's plots of average serpentine compositions are misleading. His plots are based on 15 analyses from Faust and Fahey (1962, p. 18), but, unfortunately, 7 of 15 analyses are

mixtures of two or more serpentine minerals (Faust and Fahey, 1962, p. 8-13). Serpentine mineral averages plotted in Figure 2b, on the other hand, are from what I consider to be well-identified single serpentine minerals (Page, 1966); the range of MgO and H₂O in serpentine minerals in Figure 2b is from the same source. Approximately 10 percent of the analyses of ultramafic rocks in Figure 2b have MgO contents that lie above line 1, which represents the upper limit of MgO in serpentine minerals. Most of these analyses could form a serpentinite containing a mixture of 10 percent brucite (6.9% MgO) and 90 percent serpentine if fully serpentinized. This is the ratio of brucite to serpentine suggested by Thayer (1966, p. 692).

Finally, both Thayer's and my own treatments of analyses neglect to distinguish between the two distinct types of "alpine" serpentinites, and the conclusions drawn from them are probably misleading. The two types of "alpine" serpentinites may be distinguished on the basis of the mineralogy of the alteration assemblages. One type consists of lizardite, chrysotile and magnetite with or without brucite, and the other type consists of antigorite, talc, magnetite and magnesite with or without brucite. Combinations of these assemblages are known to occur, but the field relations and mineral assemblages have not been described in detail in any one locality. Antigoritic serpentinites generally occur in metamorphic rocks with grades of metamorphism above the high green-schist facies (Wilkinson, 1953; Du Rietz, 1935, 1956; Coleman, 1966; Chidester, 1962). Lizardite-chrysotile serpentinites occur in rocks of lower grade of metamorphism (Page, 1966; Hostetler and others, 1966; Coleman, 1966). The process and history of formation of antigoritic serpentinites in particular appears to be complicated and they probably should not be included in arguments as the constant volume or composition during serpentinization. Until enough analyses of serpentinites with well-identified mineral assemblages are available for comparison, discussions of constant volume versus constant composition serpentinization are inherently oversimplified.

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SERPENTINIZATION CONSIDERED AS A CONSTANT VOLUME
METASOMATIC PROCESS: A REPLY¹

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In his discussion of my paper N. J. Page adheres to the belief, expressed by Hostetler, Coleman, Mumpton, and Evans (1966, p. 75), that:

“Extensive brucite formation during serpentinization indicates . . . , unless massive amounts of both magnesia and silica are removed from the ultramafic mass, volume increases of about 40 percent. Field evidence supporting such migration is generally lacking.”

In direct contradiction to this belief is my conclusion (p. 707) that:

“The physical evidence leaves little room for argument . . . but that serpentinization is essentially a constant volume metasomatic process which requires removal of about 30 percent by weight of the original bivalent oxides and SiO₂ in peridotite.”

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